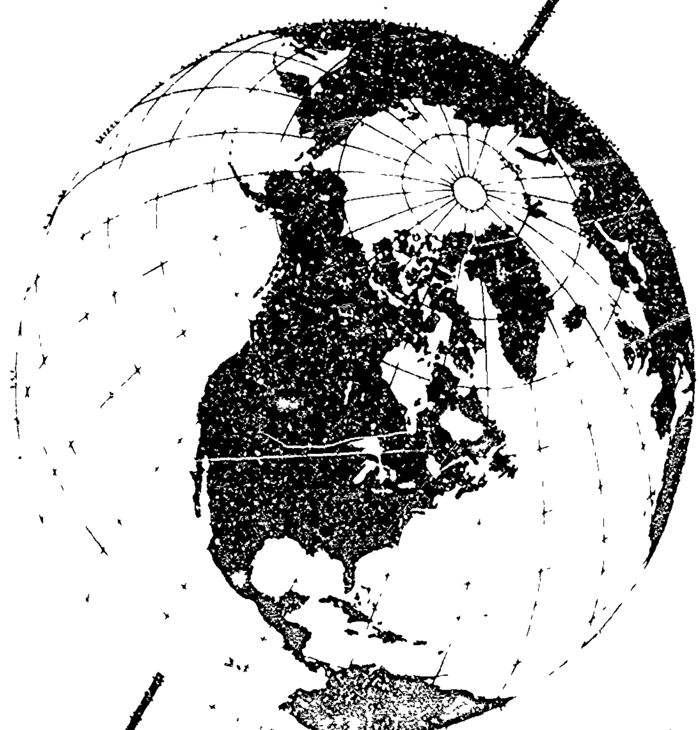
Special Report 31

JULY, 1959

Snow Studies and Other Observations - Operation King Dog, Sondrestrom, Greenland



U. S. ARMY
SNOW ICE AND PERMAFROST
RESEARCH ESTABLISHMENT
Corps of Engineers

Special Report 31

JULY, 1959

Snow Studies and Other Observations - Operation King Dog, Sondrestrom, Greenland

by Chester C. Langway, Jr.

U. S. ARMY SNOW ICE AND PERMAFROST
RESEARCH ESTABLISHMENT
Corps of Engineers
Wilmette, Illinois

PREFACE

This report presents the snow and ice data and other observations made by USA SIPRE during Operation King Dog, a field reconnaissance by the Transportation Arctic Group to select a feasible access route from Sondrestrom Air Base onto the Greenland Ice Cap. CWO Silas Bowling, USA Transportation Arctic Group, was Project Officer and Mr. Chester C. Langway, Basic Research Branch, USA SIPRE, accompanied the operation as glaciologist.

A more comprehensive technical report on Operation King Dog is being compiled by USA Transportation Arctic Group and will discuss the historical development, planning, logistics, and the military application of the operation.

This report was prepared by Mr. Langway under the general direction of Mr. J. A. Bender, chief, Basic Research Branch.

Walter H. Parsons Jr.
WALTER H. PARSONS, JR.
Colonel, Corps of Engineers
Director

Manuscript received 15 May 1958.

CONTENTS

	Page
Preface	ii
Introduction	1
Overland route: Sondrestrom Air Base to the ice-cap access (SOTO)	1
Over-ice route: SOTO to mile 76.0	5
Comments on Trafficability	10
Overland route	10
Ice-cap route	12
General comments	12
Appendix A: Uncorrected altimeter readings along the ice-cap trail from SOTO to mile76.0	
Appendix B: Past temperatures at Sondrestrom Air Base	
Appendix C: Weather record, SOTO - mile 76.0 - SOTO	

ILLUSTRATIONS

Figure		
1.	Sondrestrom, Greenland, Overland access route, Operation King Dog	2
2.	View looking from the Watson River basin east	3
3.	Snout of Russell Glacier	3
4.	Elevation and snow accumulation along ice-cap access route	7
5.	Snow temperatures at mile 76.0	7
6.	Pit 1 along ice-cap access route	8
7.	Pit 2 along ice-cap access route	8
8.	Pit 3 along ice-cap access route	10
9.	Skirting around bedrock outcrops at the snout of the Russell Glacier	11
10.	Mile 3:5 from SOTO	11
11.	Mile 4.5 from SOTO	12
12.	Mile 12.5 from SOTO	12

TABLES

Table		
I.	Lake data	4
II.	Distance traveled	5
III.	Height of ice hummocks	6
IV.	Stratigraphic symbols	9

SNOW STUDIES AND OTHER OBSERVATIONS - OPERATION KING DOG SONDRESTROM, GREENLAND

by

Chester C. Langway, Jr.

INTRODUCTION

The objective of Operation King Dog was two-fold: (1) to select a winter access route from Sondrestrom Air Base over rough terrain, river and lake ice to the edge of the Greenland Ice Cap (SOTO); and (2) to decide upon the best possible route from the edge of the Ice Cap through the hummocky ablation zone and crevasse areas to the firn line and out onto the dry snow. This report presents a general description of the route and briefly discusses the results of observations along the trail.

The field reconnaissance was made during the period 21 March to 26 April, 1958. Air support was provided by two H-19 Sikorsky helicopters and five pilots. The primary use of the helicopters was for reconnaissance, which reduced considerably the foot survey necessary for selecting a tentative route, and for re-supply missions. Four weasels were used on the trip, three modified at Fort Eustis especially for this operation, and one obtained from Transportation Arctic Group, Thule, Greenland. The three weasels from Fort Eustis have modified elongated metal bodies and two people can sleep in each; one on a folding shelf that doubles as a desk top during operating hours, and the other on the floor. One weasel was equipped with a ground to air transmitter-receiver set and a crevasse detector recorder, and the other two with standard Signal Corps 506 receiver-transmitter. Two 1-ton cargo sleds were air-dropped at mile 12.5 and used from SOTO to the endpoint (mile 76.0) and back to mile 12.5 where they were air-lifted back to Sondrestrom. All four weasels had minor mechanical breakdowns (e.g., thrown tracks, carburetor trouble, clutch disorders, failures of personnel heaters, etc.) at one time or another during the trip. On the return trip, two weasels broke down at SOTO and had to be towed the 25 miles back to Sondrestrom.

The terrain leading to the Ice Cap does not have excessive relief. It generally consists of rounded hills and some fairly level plains. Between Sondrestrom Air Base and the ice-cap access point (SOTO), the route trends E to NE along the north bank and ice surface of the Watson River, around the toe of the Russell Glacier and then NE up the terrace level and river ice of the Helen River, across Lake Marilyn, up and over a ridge to Glacier Lake, then due east over the end moraine that separates the North and Russell glaciers (Fig. 1). The route is approximately 25 miles long and rises about 2000 ft between Sondrestrom Air Base and SOTO.

The Ice Cap access point (SOTO) is situated at the junction of the N h and Russell glaciers. The elevation at this point is 2010 ft (uncorrected altimeter reading). From SOTO, the route over the Ice Cap trends north and then veers almost due east along the N67°10' latitude position. The marginal, or ablation zone, exists between SOTO and the 6300-ft contour line on the Ice Cap and is approximately 80 miles wide at this latitude. This marginal zone is characterized by an extremely hummocky ice surface for the first 5 miles, gradually diminishing at mile 23.0, to a smoother gently undulating sastrugi-covered snow surface. Many frozen thaw lakes and dry melt-water stream beds of large dimensions were encountered in the marginal zone. The only observed crevasses, four in number, were 1 to 2 ft wide, but it is suspected that others were crossed.

OVERLAND ROUTE: SONDRESTROM AIR BASE TO THE ICE-CAP ACCESS (SOTO)

As the area was considered with the idea of providing a potential winter route, lake and river ice surfaces were utilized whenever possible in order to facilitate travel. For the first leg of the overland route, an existing dirt road from BW-8 to the northwestern slope of Sugar Loaf Mountain (elevation 1200 ft) was used, (5.4 statute miles). No snow drift conditions existed along this road and snow cover was sparse (2-6 in.) on the slopes and banks of the adjacent ridges.

From the northwestern slope of Sugar Loaf Mountain, the trail generally followed the surface topography at the 400 ft contour level, to the northeast. Five small lakes

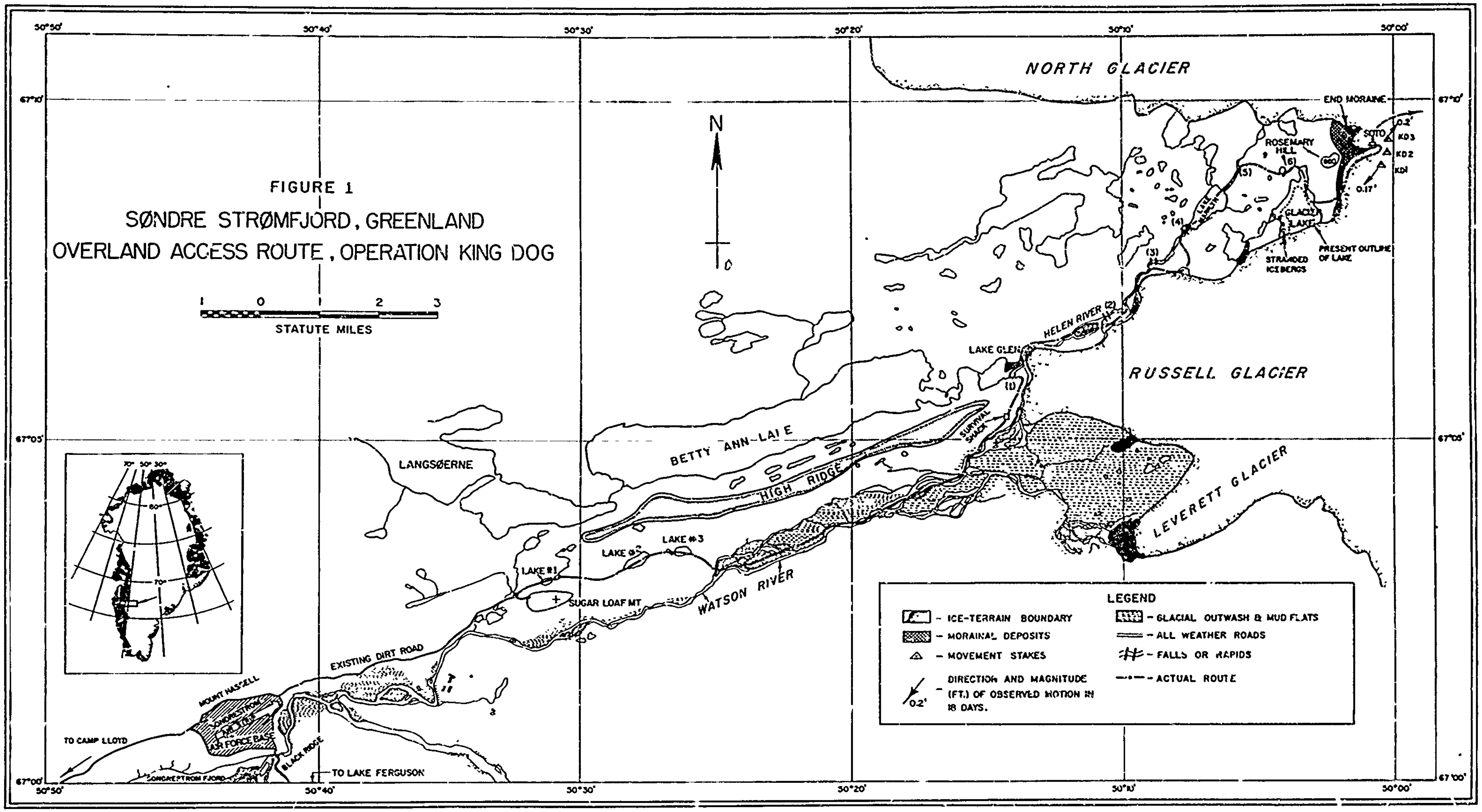


FIGURE 1
SØNDRE STRØMFJORD, GREENLAND
OVERLAND ACCESS ROUTE, OPERATION KING DOG

were crossed in this section; data were collected on the three largest lakes (see Table I). Snow cover was light, with a 4-8 in. accumulation in the valleys and on the slopes and with the ridges nearly snow-free.

After crossing Lake #3, the trail veered to the southeast for 1/2 mile, then followed the river ice surface, flood plains, and terrace levels of the Watson River for 5 1/2 miles to the southwestern terminus of the Russell Glacier. The Watson River has a wide basin and, because the main river channel meanders, much of the surface travel was over the snow-covered (3-6 in.) gravel and sandy floodplains and banks. Where the ice surface of the Watson River was used to travel, the ice ranged from 51 to 60 in. in thickness (130 to 150 cm). Snow cover was sparse, 4-8 in. accumulation, with an occasional drift 3-5 ft high, which did not interfere with surface travel. It was difficult to ascertain the actual river ice surface because of the meandering nature of the Watson River combined with its relatively flat basin, and the fairly uniform snow cover. A dead reckoning course was usually taken. The trail then paralleled the cliff face of Russel Glacier (160-180 ft high, Fig. 3) to the north for approximately one mile over a section of very rocky terrain to Lake Glen (see Table I). From the eastern end of Lake Glen, the trail went up and over a morainal deposit with gentle slopes and on to the northern terrace level of Helen River. This terrace was followed almost due east for 1 mile and then the trail crossed on to the river ice and flood plains for 1/2 mile. Rapids at the upper end of the flood plain required the trail to leave the river basin and cross a steep snow-covered outcrop that forms the south bank of the Helen River and separates the river from the Russell Glacier, crossing this moraine and snowdrifts for 1/2 mile before returning to river ice.

At this point, the Helen River trends NE and becomes sinuous for approximately one mile. A section of the river ice in this area displayed visible signs of surface melting. Data were obtained on this melt phenomenon. Another set of rapids at the northern end of this sinuous portion of the river required the trail to swing to the east, up a steep incline, and then down again onto the river ice one mile upstream. From here, there is approximately 1/2 mile of difficult trail up and over terraces, morainal deposits, and snow drifts to the SE shore of Lake Marilyn (see Table I). The Helen River ice was 50 to 62 in. (130 to 158 cm) thick, measured at the center of the main river channel.

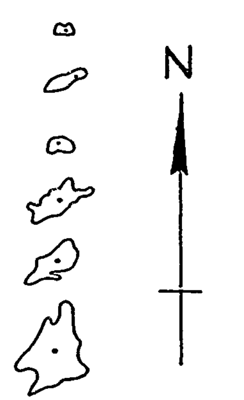
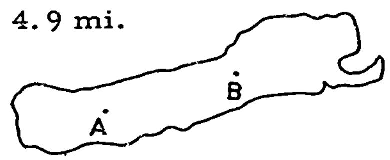
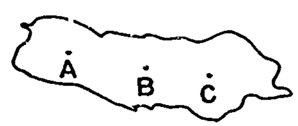
The trail then crossed Lake Marilyn to the northeast and went up the river valley at the NE end for 1/2 mile. At this location, the best route appeared to be up a very steep slope of a terrace bank drifted with 3 to 10 ft of crusted snow (did not support a weasel). It was necessary to "doublehead" the weasels in order to make this grade.

Once on top of the terrace plain, the trail followed a steep grade across the ridges and into the valley onto terrace levels of Glacier Lake (see Table I), skirting around

Figure 2. View looking from the Watson River basin east towards snout of Russell Glacier. 15 April 1958.

Figure 3. Snout of Russell Glacier showing pinnacled nature of the ice surface. The cliff face is approximately 160-180 ft high. 27 March 1958.

Table I. Lake data. Lakes traversed on overland route, Operation King Dog.

Lake	Elev. (ft)	Day	Time	Length and shape of lake (statute miles)	Ambient air temp (C)	Snow - Ice interface temp (C)	Total ice thickness (cm)	(in.)	Snow - Ice thickness (cm)	(in.)	Snow cover (cm)	(in.)
# 1	436	3/23	1400	0.2 mi. 	-12	-11	160	63	2.5	1.0	7.6	3.0
# 2	438	3/23	1500	0.5 mi.	-13	-11	140	55	7.6	3.0	10	4.0
# 3	522	3/28	1730	0.3 mi.	-19	-15	142	56	5.1	2.0	4	1.5
Lake Glen	710	3/28	1000	0.7 mi.	-23	-21	157	62	6.4	2.5	3	1.0
Lake Marilyn	1108	3/29	1030	0.8 mi.	-15	-15	124	49	10.2	4.0	20	8.0
Glacier Lake	1291	4/2	1530	1.2 mi.	-10	-10	130	51	15.2	6.0	20	8.0
Largest lakes in vicinity of Sondrestrom Air Base.												
Betty Ann Lake	710	3/28		4.9 mi. 								
Location A			1245		-20	-18	140	55	1.9	0.75	8	3.0
Location B			1330		-21	-16	140	55	1.3	0.50	5	2.0
Lake Ferguson	223	3/24		3.5 mi. 								
Location A			1130		-16	-12	142	56	1.9	0.75	6	2.5
Location B			1230		-15	-11	135	53	1.3	0.50	10	4.0
Location C			1330		-16	-14	145	57	1.3	0.50	9	3.5

(1) Elevations are given as uncorrected altimeter readings.
(2) Ambient air temperature is the air temperature 6 in. above the lake surface.
(3) Snow - ice interface temperature is that temperature taken between the ice surface and the snow cover boundary.
(4) Thickness determinations were taken at the approximate center of each lake except where more than one thickness measurement was made, as indicated in the lake diagram.

the northern end of Glacier Lake and then swinging almost due south around the southern slope of Rosemary Hill (660). From this point, the trail went due east, up and across the end moraine that separates Russell and North glaciers and onto the hummocky glacial ice.

Table II. Distance traveled.

From	To	Distance (statute miles)
East end of runway at Sondrestrom Air Base	Sugar Loaf Mt.	5.4
Sugar Loaf Mt.	Survival shack (at terminus of Russell Glacier)	9.0
Survival shack	End moraine (SOTO)	10.0
Total distance of overland trail from Sondrestrom Air Base to SOTO		24.4

On the return trip, the same trail was followed to the survival shack at the terminus of the Russell Glacier. A noticeably thinner snow cover existed on the terrain during the return trip. The southern slopes and the ridges were bare and only a slight snow cover occupied the northern slopes and the shaded valleys. Visible melting of the snow was occurring on the southeast slopes of Rosemary Hill (660). The air temperature at 1230 hr was +4C at this location. Glacier Lake showed signs of surface melting where windblown glacial debris had accumulated. Because of the complete absence of snow cover, eight distinct terrace levels of Glacier Lake were visible. It appeared that this lake, which abuts the glacial cliff face, was occupying only approximately 1/2 of its maximum summer areal extent and contained about 1/4 of its maximum water supply. Substantiating this were stranded icebergs (40-60 ft in diam) 70 to 80 ft above the lake ice surface on the SW terrace of Glacier Lake.

At Russell Glacier, it was decided to attempt an alternate route back to Sondrestrom. From a helicopter reconnaissance, it appeared that a natural trail existed in a major fault valley located at the top of the ridge that separates Betty Ann Lake and the Watson River Basin. The access to this fault valley was steep and required "double heading" of the weasels (however, two of the four weasels were inoperative and had required towing from the end moraine at SOTO). Once the steep incline was ascended, no outlet appeared to exist except down the very rough and drainage-dissected south slope of the ridge onto the Watson River basin. This was not a feasible path, so the trail was back-tracked to the Russell Glacier and the remainder of the route to Sondrestrom followed the trail used on the outward trip.

Twice on the homeward traverse, the weasels broke through the river ice (17 April). It was noted that, for a week prior to this, temperatures were above freezing along the trail during the daylight hours and the weather was clear and sunny. The weasels sank down to their floors, but traction was maintained and no serious difficulty was encountered. It appeared that the ice that collapsed consisted of a weak 3-4 in. shell layer that had free water flowing beneath it and more river ice below, which also collapsed when the surface layer was broken. One week later, when a foot traverse was made, these collapse sections of the river ice were completely refrozen due to a change in air temperature.

OVER-ICE ROUTE FROM SOTO TO MILE 76.0

For the first 11 miles of the Ice Cap access route, the ice hummocks present a problem to surface travel. Surface travel without sleds could be classified as hazardous from mile 0 (SOTO) to mile 3.0; very rough from mile 3.0 to mile 5.0; and rough from mile 5.0 to mile 11.0. From mile 11.0 to the last visible surface signs of the ice hummocks, at mile 23.0, the surface becomes more gentle with only an occasional ice hummock protruding through the snow surface. After mile 23.0, the snow surface is gently undulating with an overall average grade of approximately 1% and presents no trafficability problem, at this time of year, for any type of oversnow vehicle. Without some

modification of the irregular ice surface for the first 5.0 miles, it would be nearly impossible to tow a sled behind a weasel or to traverse this section with any vehicle having wider tracks than a weasel.

Table III. Height of ice hummocks.

Mile	(ft)
0 - 3	5 - 40
3 - 5	5 - 15
5 - 125	2 - 8
12 - 23	1 - 3

These ice hummocks are bare glacial ice and their configuration represents previous year's melt surface. These patterns are products of surface melt and surface drainage. The wind prevailed from the southeast to south-southeast consistently during the entire trip. This wind action creates a bare ice surface on the southeast slopes of the ice hummocks and a sparse (4-8 in.) snow cover on the leeward sides, with some drifting of snow along the ridges and in the troughs. Eastward from SOTO there is a gradual increase of snow cover above the hummocky ice surface. This is partly due to the shape of the hummocks, which become less precipitious and more rounded, although still retaining considerable heights (2-8 ft) to mile 12.5.

Wind velocities ranged from zero (rare, and observed only once immediately preceding a whiteout) upward to 40 or 50 knots, averaging 10-20 knots during the trip. Fair weather was associated with SE and SSE wind directions. When the wind shifted to the south or SSW, it generally accompanied storms and bad weather.

Air temperatures fluctuated diurnally and with elevation. Maximum ambient air temperature recorded on the Ice Cap during the operational period was 0C; this was obtained on several occasions: 5 April at 2300 hr; 6 April at 0700 hr and 1700 hr; 8 April at 1030 hr; and 9 April at 1350 hr. The minimum air temperatures recorded were: -29C at 0100 hr (13 April); and -28C at 2400 (12 April). Generally, temperatures were higher during the daylight hours averaging between -6C and 0C for the trip. As would be expected temperatures lowered after the sun went down, averaging between -6C and -15C. (Weather data for SOTO-mile 76 are given in Appendix C).

The elevation profile (Fig. 4) represents readings taken every 1/4 mile for the first 12.5 miles and every 1/2 mile thereafter (see Appendix A). Two calibrated Wallace and Tiernan altimeters (Corps of Engineers' Model #FA181) were used to obtain elevations. The altimeter scale is divided into 20-ft increments with 1 mm spacing and it was possible to interpolate to differences of 5 ft in elevation (±5 ft). Distances were measured on the odometers of the weasels and temperature taken using a Weston dial thermometer (±1/2C).

The Ice Cap end-point (turn around station) was located 76.0 statute miles from SOTO at an elevation of 6108 ft (uncorrected altimeter reading).

Three pit studies were conducted along the Ice Cap route at mile 12.5; mile 50.0; and mile 70.0 (Figs. 6-8). At mile 76.0, a 3-in. hole was augered to 20 ft (6 m) and a temperature profile was obtained (Fig. 5). The cores obtained at mile 76.0 had 5-8 cm thick ice layers interbedded with densified snow and icy firn, showing that this location is in the transitional zone of the firn.

The net snow accumulation as determined by the pit studies and probing is shown in Figure 4. This represents the accumulation since the end of the 1957 melt season (approximately 1 October) up to the period of the probings and pit studies (mid April). The major portion of the net accumulation is deposited within this approximately 6-month period.

A large, dry surface-melt stream bed was crossed at mile 14.5. It meandered in a NE to SW direction for approximately 30 or 40 miles. Where its channel was not filled with wind-blown snow, it was 30-35 ft wide, 30-35 ft deep. Other smaller surface-melt stream beds were crossed, but they also were filled with wind-blown snow. In general, dry stream beds, frozen thaw lakes, and narrow crevasses present no obstacle to surface travel during the winter months as they are sufficiently filled or bridged over with snow.

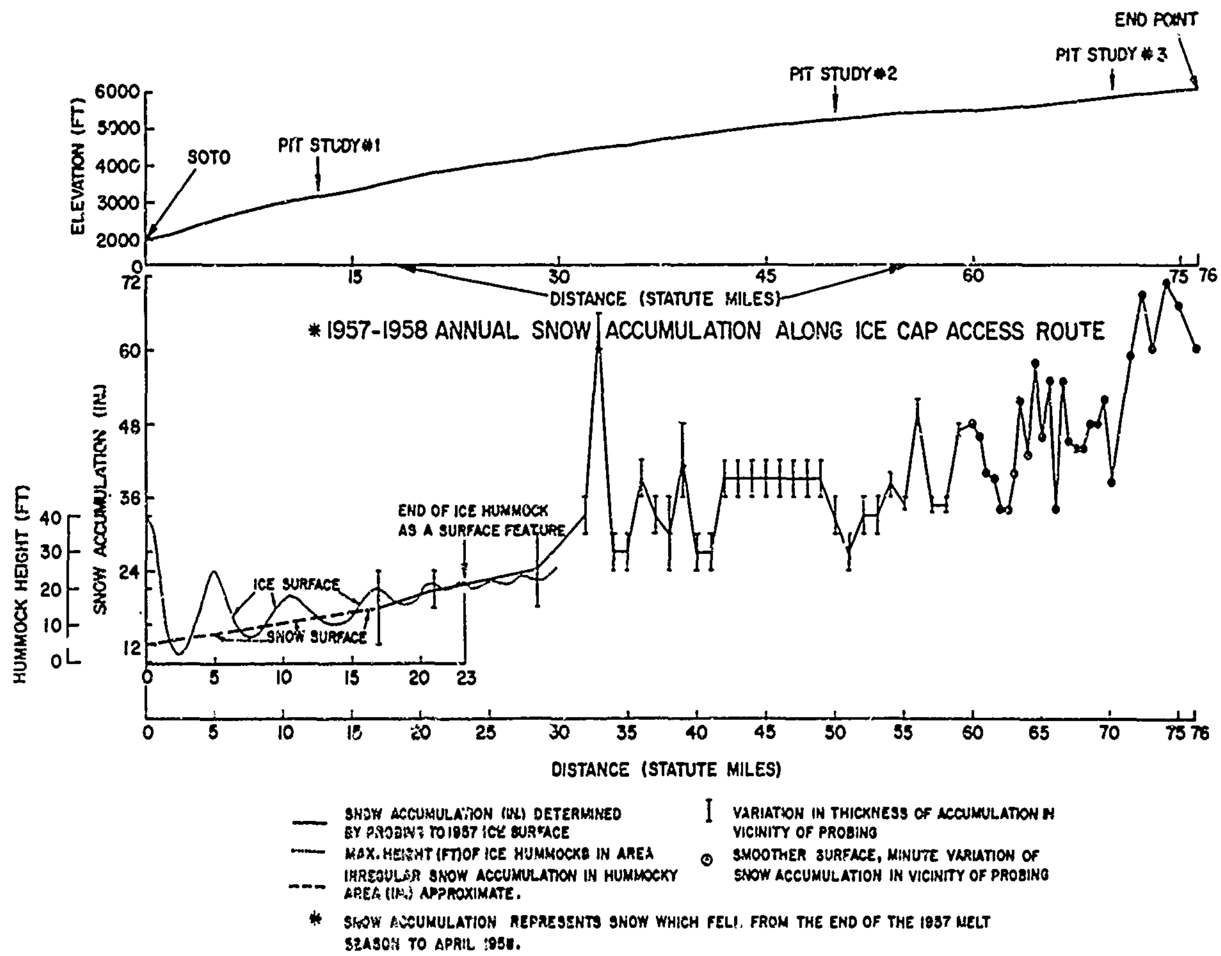


Figure 4. Elevation and snow accumulation along ice cap access route, SOTO to mile 76.0.

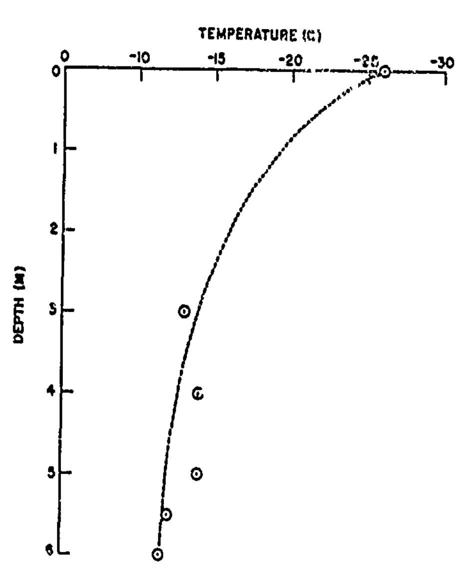


Figure 5. Snow temperatures at mile 76.0. Lat. N67°10'; Long. W47°11'. Time: 1745 hr, 13 April 1958. Wind SE 18-20 knots.

A 3 in. hole was augered to a depth of 20 ft (6 m). A Weston dial thermometer was lowered on a length of cord, left for 5 min, then rapidly withdrawn. Each point represents the mean of four readings. As the core showed a sequence of 5-10 cm ice layers, the temperatures were undoubtedly affected by percolating melt water. Because the air temperature (-26C) was lower than the snow temperatures, the values could be as much as 1 deg too low. The depth of the hole, limited by the availability of extension rods, was not sufficient to obtain a mean annual temperature for this location. However, the values give a first approximation of the temperatures with depth in this area.

Position: Lat. N67°08'44"
Long. W49°38'44"

Location: Mile 12.5

Date: 5 April 1958

Elev.: 3140 ft (uncorrected altimeter)

Ambient air temp: 0 to -4C

Snow accumulation: 117 cm

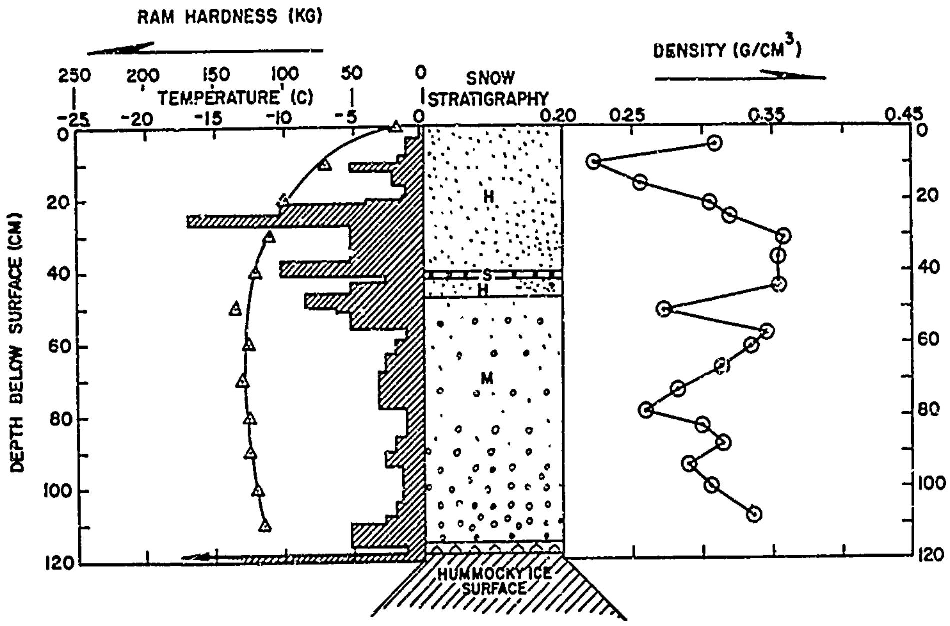


Figure 6. Pit 1 along Ice-Cap access route. Entire area is underlain with ice hummocks, but the snow surface is horizontal. Therefore, the amount of snow cover would depend upon the location of the pit in reference to the crest, limb, or trough of an ice hummock. This location is a basin area gently sloping upward to the east. No stratigraphy, in its true sense, exists at this location, or at the other pits, but the different types of snow accumulated since the last melt season are distinguished.

Position: Lat. N67°11'50"
Long. W48°19'58"

Location: Mile 50.0

Date: 9 April 1958

Elev.: 5230 ft (uncorrected altimeter)

Ambient air temp: 0 to -4C

Snow accumulation: 84 cm.

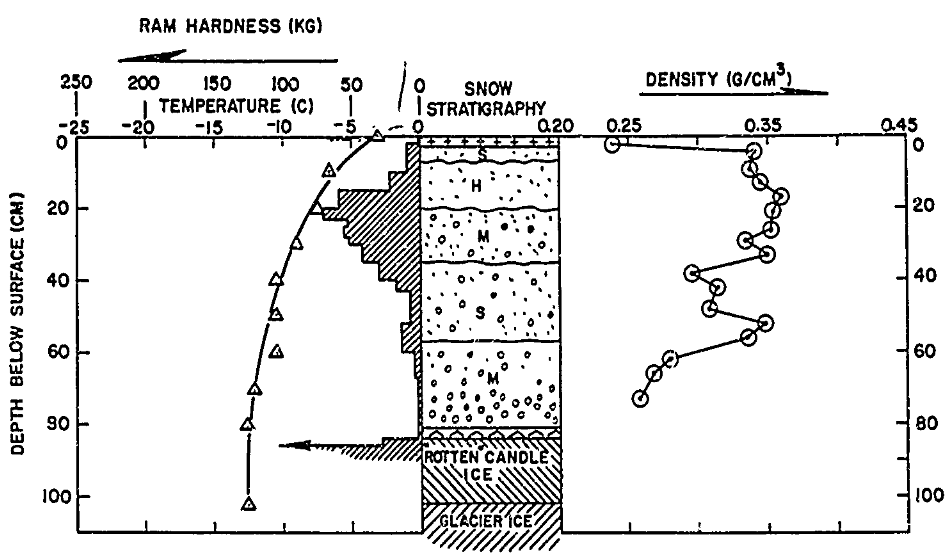
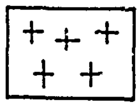
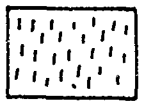
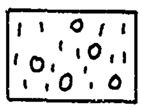
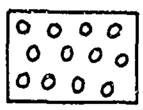
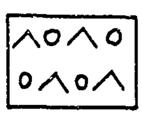
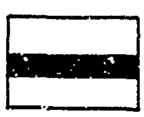
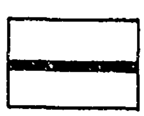
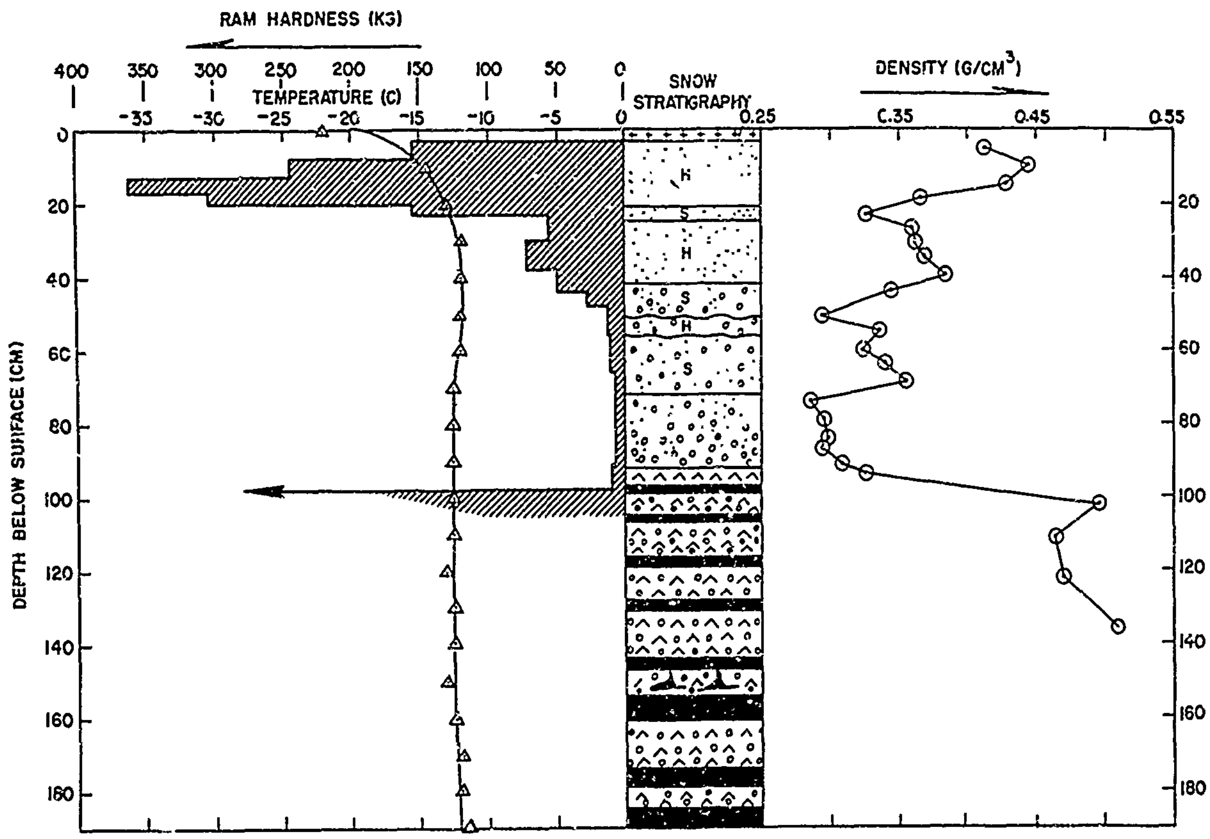


Figure 7. Pit 2 along Ice-Cap access route. The 18-cm layer of "rotten" (candle) ice at 84-102 cm, consisting of equigranular loosely bonded grains between 0.3 and 0.8 cm diam, represents last melt season's weathered ice surface. Below this is glacier ice. The snow-ice interface is horizontal, but this location is still in the ablation zone. Snow accumulation varied between 80-105 cm. The temperature profile was taken immediately (12 noon) but the remainder of the pit study was delayed due to the rise in temperature that accompanied the whiteout and caused moisture to condense on the snow tubes. Approximately 3 cm of new light and fluffy snow fell during the storm that followed the whiteout.

Table IV. Stratigraphic symbols*

	New snow
	Fine-grained, < 1 mm
	Medium-grained, 1-2 mm
	Coarse-grained, usually poorly bonded, 2-4 mm
	Depth hoar
	Depth hoar and icy firn
	Ice layer
	Discontinuity between adjacent layers
	Wind crust, represented as a wavy line, but usually horizontal and between 1-2 mm thick
	Ice gland 1, and lens 2
HARD, H MEDIUM, M SOFT, S	Relative index of snow hardness by finger probing
△	Temperature
⊙	Density

* Modified after Carl Benson (USA SIPRE Research Report 26, in preparation).



Position: Lat. N67°09'43"
Long. W47°26'02"

Location: Mile 70.0

Date: 12 April 1958

Elev.: 5870 ft (uncorrected altimeter)

Ambient air temp: -28 to -23C

Snow accumulation: 97 cm

Figure 8. Pit 3 along Ice-Cap access route. The base of the depth-hoar layer represents last summer's melt surface. Below this, there is a sequence of ice layers underlain with an icy firn - depth hoar stratum. Although this location is in the ablation zone, there is a net annual accumulation that is represented by an ice layer - icy firn and depth hoar interval. The cyclical interval is relatively uniform and suggests a constant ablation period during the observable preceding years. Of course, any hiatus is not detectable.

Movement stakes were placed at three locations in the SOTO region. A 330-ft base line was established from Rosemary Hill (660), and the angles were turned with a Wild T-2 theodolite. A total time of 18 days elapsed between readings and approximately 0.2 ft of movement was recorded on both KD-3 and KD-1 positions. On position KD-2 (center location) no movement was observed. The direction of movement is indicated on Figure 1.

COMMENTS ON TRAFFICABILITY

Most of the more difficult surface features encountered along the trail were documented by the 1200 ft of 16 mm color film, taken over the entire access route. Emphasis was placed upon the first 12.5 miles of the ice-cap trail, where the difficult ice hummocks exist and trafficability presents the worst problem.

Overland route

As the route would be used primarily for operations during the winter months, very little engineering work would be necessary on the overland section to improve the surface and make it readily accessible to military tractors. The major part of the route would utilize the available ice surfaces. Whenever it was necessary, or more feasible, to use the terrace levels and river banks, little difficulty was encountered entering or leaving these ice surfaces. However, several short portions of the overland route

Figure 9. Skirting around bedrock outcrops at the snout of the Russell Glacier. Looking north, Russell Glacier is to the southeast. 28 March 1958.

Figure 10. Mile 3.5 from Soto. Trafficability was hazardous; here a weasel has slipped off a narrow snow ridge and rests against an ice hummock. 4 April 1958.

deserve special mention because of some specific difficulty encountered on it during passage. These portions are numbered on Figure 1.

(1) Approximately one mile north of the survival shack is a section 1/4 mile long, where a boulder field and angular rock outcrops presented some difficulty for weasel travel (Fig. 9). The danger of throwing a track always exists when crossing this type of terrain with a weasel, so great care was exercised here. With an adequate snow cover (about 1 ft) no improvement of this section would be necessary, but there were only 2 to 4 in. of snow during this period. Very little work would be necessary to improve this condition; a standard D-8 tractor with a blade might be sufficient.

(2) The first set of rapids encountered on the Helen River necessitated leaving the river ice and crossing over a morainal deposit on the south bank, but the morainal grade is not sufficient to create any major difficulty.

(3) The second set of rapids required climbing a steep rocky river bank, then across and down an adjacent steeply sloping hill. Both sets of rapids present no particular problem as it is not too difficult to leave the river ice surface and re-enter a short distance upstream.

(4) Before reaching the southern shore of Lake Marilyn, the river narrows and the presence of a number of falls requires the trail to leave the Helen River for about 1/2 mile. The land surface adjacent to the river has very rugged and steep undulating slopes and could be improved with some cut and fill. Care should be exercised in crossing the rocky and bouldery shore of Lake Marilyn, or any similar location, because of the danger of throwing tracks with weasel-type vehicles. (Two tracks were thrown at this location, even though great care was taken.)

(5) Approximately 1/2 mile from the northern shore of Lake Marilyn, a steep terrace slope required double heading of the weasels to reach the terrace level. The

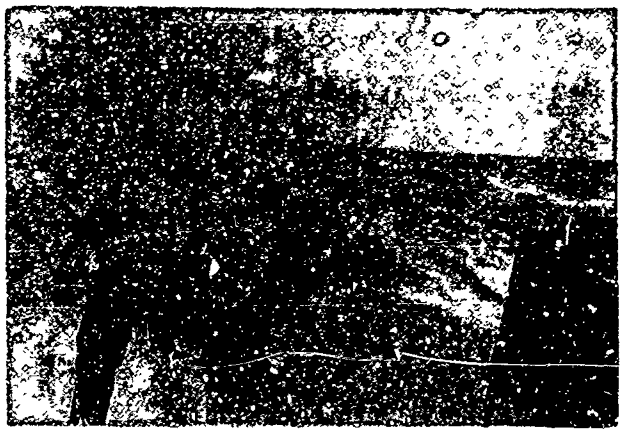


Figure 11. Mile 4.5 from SOTO. Narrow passage between ice hummocks. 4 April 1958.

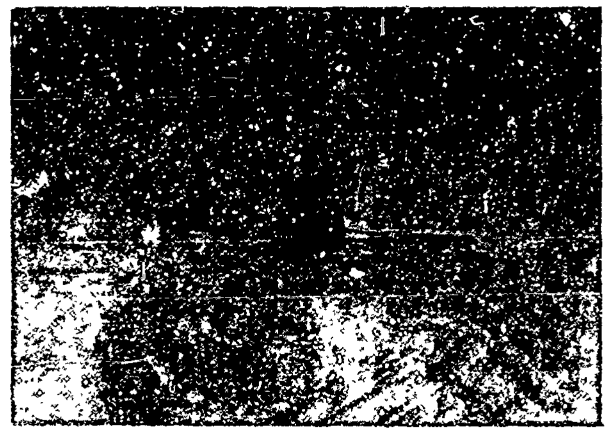


Figure 12. Mile 12.5 from SOTO. Crevasse detector on lead weasel. 7 April 1958.

terrain from this point to Glacier Lake has considerable relief, but presents no major trafficability problem.

(6) The grade down to Glacier Lake and up and over the end moraine is of the order of 25-30%. Because of the length of the slopes (approximately 1/4 mile in each case) some difficulty may be expected if surface vehicles were towing sleds. This difficulty may be minimized by careful routing of this section.

Ice-cap route

Once ascent to the glacier has been made, a different type of trafficability problem evolves. From SOTO eastward to mile 12.5, ice hummocks present a real problem to any standard type of oversnow vehicle (Figs. 11, 12). Weasels were used in this preliminary reconnaissance and, because of their extreme mobility (no sleds were towed in the hummocky area) and small width, the trail was selected on the basis of accessibility for this vehicle. This trail was very sinuous and many of the narrow ice gorges barely allowed passage (Fig. 11). This does not mean that a way could not have been found for wider vehicles. However, it would be difficult without modifying the existing hummocky ice surface. Individual precipitous hummock areas crop up along the way, with slopes up to 60 deg. It would be inadvisable to try to cross these with vehicles larger than a weasel or while towing sleds. Switchbacks and sharp turns along narrow ridges of ice were plentiful. On two occasions, even though great care was exercised in driving, the weasels slid into the adjacent troughs and had to be towed out.

Although the first 4 to 5 miles presented the greatest difficulty, the hummocks were a hindrance to travel out to mile 12.5. From mile 12.5 no difficulty was encountered, other than the usual ice-cap locomotion problems.

General comments

Minor route adjustments to raise the overland route off the river and lake ice and some additional engineering work, besides what has been mentioned above, such as: local cut and fill, local blasting, and general blade work, would make the overland route accessible throughout the year. This would enable the storing of supplies and equipment at a cache point near the glacier and then taking it over the ice surface during the winter months.

Once on the ice, any type of surface travel would definitely be restricted to the winter months because of the summer melt conditions, primarily the very wide summer slush belt beyond the hummocky area. In principle, it would be possible to construct a summer trail through the hummocky area, but the slush belt must be considered impassable.

APPENDIX A: UNCORRECTED ALTIMETER READINGS ALONG THE ICE-CAP TRAIL FROM SOTO TO MILE 76.0

	Mile	Elev (ft)	Mile	Elev (ft)	Mile	Elev (ft)	Mile	Elev (ft)
SOTO	0.0	2010	10.75	3045	30.5	4408	52.0	5315
	0.25	2025	11.0	Miss	31.0	4413	52.5	5315
	0.50	2035	11.25	3100	31.5	4418	53.0	5310
	0.75	Miss*	11.5	3130	32.0	4453	53.5	5318
	1.0	2055	11.75	3140	32.5	4470	54.0	5380
	1.25	2125	12.0	3150	33.0	4475	54.5	5438
	1.5	2105	12.25	Miss	33.5	4483	55.0	5458
	1.75	2140	12.5	3140	34.0	4488	55.5	5448
	2.0	2160	13.0	3195	34.5	4515	56.0	5418
	2.25	2180	13.5	3260	35.0	4558	56.5	5403
	2.5	2210	14.0	3305	35.5	4583	57.0	5448
	2.75	2240	14.5	3323	36.0	4613	57.5	5478
	3.0	2310	15.0	3325	36.5	4638	58.0	5480
	3.25	2370	15.5	3343	37.0	4713	58.5	5508
	3.5	2400	16.0	3388	37.5	4763	59.0	5505
	3.75	2460	16.5	3423	38.0	4780	59.5	5480
	4.0	2500	17.0	3510	38.5	4810	60.0	5483
	4.25	2515	17.5	3593	39.0	4835	60.5	5500
	4.5	2550	18.0	3645	39.5	4843	61.0	5523
	4.75	2545	18.5	3670	40.0	4855	61.5	5543
	5.0	2570	19.0	3685	40.5	4890	62.0	5558
	5.25	2610	19.5	3718	41.0	4905	62.5	5583
	5.5	Miss	20.0	3748	41.5	4923	63.0	5600
	5.75	2630	20.5	3750	42.0	4955	63.5	5610
	6.0	2660	21.0	3770	42.5	4975	64.0	5608
	6.25	2700	21.5	3838	43.0	4995	64.5	5610
	6.5	2730	22.0	3900	43.5	5018	65.0	5623
	6.75	2760	22.5	3930	44.0	5033	65.5	5643
	7.0	2790	23.0	3933	44.5	5055	66.0	5655
	7.25	2795	23.5	3933	45.0	5080	66.5	5660
	7.5	2800	24.0	3970	45.5	5093	67.0	5685
	7.75	2805	24.5	4018	46.0	5095	67.5	5728
	8.0	2840	25.0	4078	46.5	5118	68.0	5763
	8.25	2870	25.5	4115	47.0	5148	68.5	5780
	8.5	2900	26.0	4120	47.5	5168	69.0	5783
	8.75	2910	26.5	4138	48.0	5175	69.5	5810
	9.0	2930	27.0	4160	48.5	5193	70.0	5873
	9.25	2925	27.5	4173	49.0	5210	71.3	5935
	9.5	2940	28.0	4195	49.5	5230	72.2	5935
	9.75	2960	28.5	4230	50.0	5233	73.0	5955
	10.0	2980	29.0	4273	50.5	5238	74.0	6013
	10.25	3005	29.5	4320	51.0	5273	75.1	6070
	10.5	3025	30.0	4390	51.5	5303	76.0	6108

*Miss notation indicates that no reading was taken at this station.

APPENDIX B: PAST TEMPERATURES (F) AT SONDRESTROM AIR BASE, GREENLAND. 6-YR PERIOD 1952-1957

Data obtained from USAF Air Weather Service Records, Sondrestrom Air Base, Greenland.

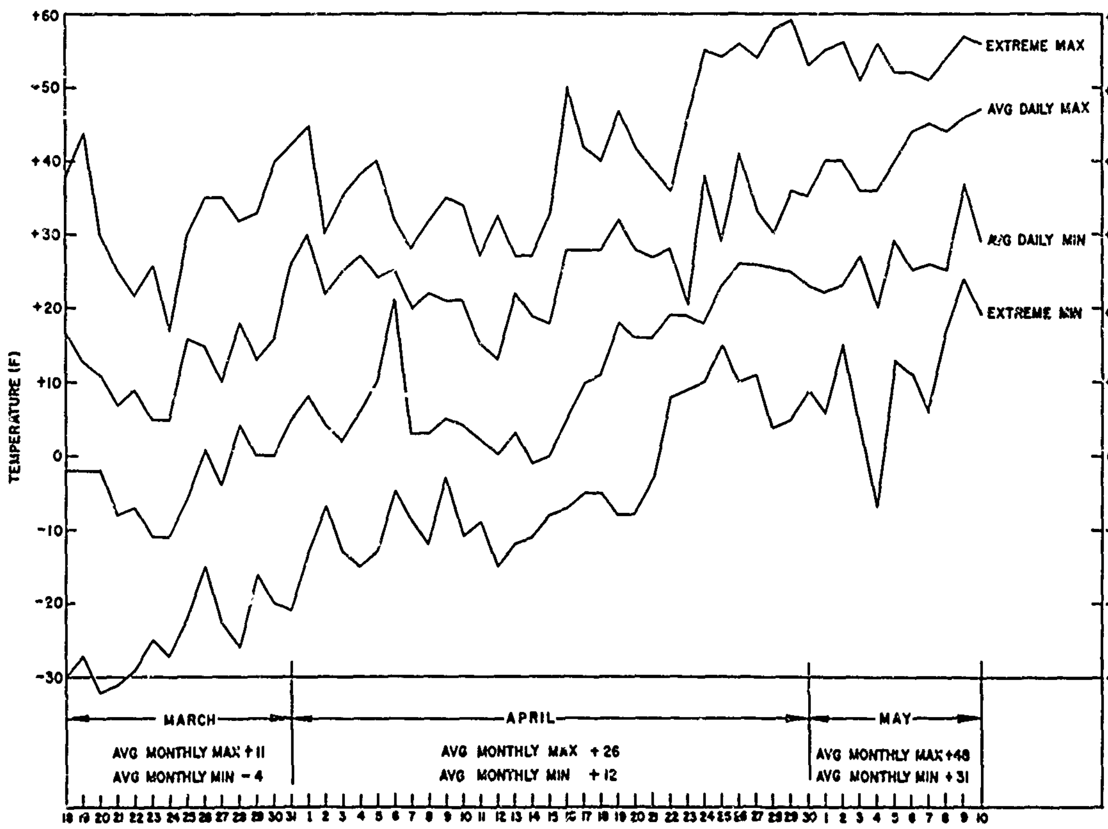
Month	Avg month max	Daily variation	Avg month min	Daily variation	Extreme max	Extreme min
Jan	5	±17	-11	±13	48	-43
Feb	6	±14	-9	±10	50	-40
Mar	11	±6	-4	±6	45	-32
Apr	26	±14	12	±13	59	-15
May	48	±11	31	±10	67	-7
June	57	±6	40	±4	74	26
July	60	±3	43	±2	70	34
Aug	57	±3	40	±6	69	30
Sept	43	±9	33	±8	66	14
Oct	30	±9	17	±9	57	-8
Nov	22	±10	6	±12	45	-42
Dec	4	±15	-10	±14	47	-40

	Extreme max	Avg daily max	Avg daily min	Extreme min
March				
18	38	17	-2	-30
19	44	13	-2	-27
20	30	11	-2	-32
21	25	7	-8	-31
22	22	9	-7	-29
23	26	5	-11	-25
24	17	5	-11	-27
25	30	16	-6	-22
26	35	15	1	-15
27	35	10	-4	-23
28	32	18	4	-26
29	33	13	0	-16
30	40	16	0	-20
31		26	5	-21
April				
1	45	30	8	-13
2	30	22	4	-7
3	35	25	2	-13
4	38	27	6	-15
5	40	24	10	-13
6	32	25	21	-5
7	28	20	3	-9
8	32	22	3	-12
9	25	21	5	-3
10	34	21	4	-11
11	27	15	2	-9
12	33	13	0	-15
13	27	22	3	-12
14	27	19	-1	-11
15	33	18	0	-8
16	50	28	5	-7
17	42	28	10	-5
18	40	28	11	-5
19	47	32	18	-8
20	42	28	16	-8

APPENDIX B (cont.)

	Extreme max	Avg daily max	Avg daily min	Extreme min
April				
21	39	27	16	-3
22	36	28	19	8
23	47	20	19	9
24	55	38	18	10
25	54	29	23	15
26	56	41	26	10
27	54	33	26	11
28	58	30	13	4
29	59	36	25	5
30	53	35	23	9
May				
1	55	40	22	6
2	56	40	23	15
3	51	36	27	4
4	56	36	20	-7
5	52	40	29	13
6	52	44	25	11
7	51	45	26	6
8	54	44	25	17
9	57	46	37	24
10	56	47	29	19

PAST TEMPERATURE MEANS FOR THE SIX YEAR PERIOD 1952-1957
AT SONDRESTROM AIR BASE



APPENDIX C: WEATHER RECORD, SOTO - MILE 76.0 - SOTO.

Date	Time (hr)	Mile	Air Temp (C)	Wind direction and velocity (knots)	Weather
April 3	0700	0	-4	windy SE	overcast
	1200	0	-1	30 SE	overcast
	1430	0	-1		sun breaking through
	1730	1.5	-1	windy SE	slight overcast
	2030	1.5	-3	windy SE	clear sky
4	0600	1.5	-5	windy SE	sunny
	0830	1.5	-6	windy SE	sunny
	0930	1.75	-2		
	1900	9.0	-3		
	2130	9.0	-5	3-5 SE	
	2210	9.0	-6	5-7 SE	
	2300	9.0	-6		
5	0700	9.0	-6	3-4 SE	sunny
	0730	9.0	-6	5-7 SE	sunny
	0845	11.0	-2	5 SE	sunny, 2/10 cover
	0900	11.5	-2		
	0930	12.5	-1		
	2300	12.5	0	10-15 SE	complete overcast
6	0700	12.5	0	windy SE	slight overcast
	1100	12.5	1	3-5 SE	slight overcast
	1330	12.5	2	2-3 SE	slight overcast
	1700	12.5	0	windy SE	slight overcast
	2000	12.5	-4	3-5 SE	clearing skies
	2100	12.5	-6	5 SE	clearing skies
7	0645	12.5	-9	7-10 SE	
	0815	12.5	-7	7-10 SE	sunny
	0930	12.5	-6	8-10 SE	
	1115	14.0	-6	7-10 SE	
	1145	14.0	-4		
	1205	14.0	-2		
	1250	17.5	-1		
	1745	17.5	-4	10-15 SE	
	2200	28.5	-8	20-25 SE	
8	0700	28.5	-6	18-20 SE	sunny
	0930	28.5	-2	15-18 SE	6/10 cloud cover
	1030	28.5	0	5 SE	clear sky, 6/10 cover
	1415	28.5	-2	3 SE	sunny
	1510	28.5	-1	5-7 SE	sunny
	1730	33.0	-5		
	1815	33.0	-6		
	1855	33.0	-6	7-10 SE	clear
	1930	39.0	-6		
	2010	39.0	-6	3 SE	
	2155	39.0	-4	5 SE	9/10 cloud cover
9	0545	39.0	-5	3-5 SE	overcast
	0630	39.0	-4	3-5 SE	overcast
	0800	42.0	-4	3-5 SE	overcast
	0900	45.5	-3	3 SE	whiteout closing
	1007	48.5	-2		
	1300	50.0	0	no wind	whiteout
	1700	50.0	-1	no wind	partly overcast
	2000	50.0	-6	no wind	
	2230	50.0	-12	5 SE	clearing skies
10	0600	50.0	-9		
	0800	50.0	-6	10-12 SE	partly overcast
	1030	50.0	-1	8-10 SE	partly overcast
	1330	50.0	-1	15-20 S	haze, whiteout

APPENDIX C (cont.)

Date	Time (hr)	Mile	Air Temp (C)	Wind direction and velocity (knots)	Weather
April 10	1500	50.0	-3	10-15 SW	
	1600	50.0	-5	12-15 SSW	whiteout conditions
	1700	50.0	-5	18-20 SSW	storming
	1900	50.0	-6	18-20 SSW	visibility 500 ft
	2150	50.0	-7	18-20 SSW	blizzard
	2230	50.0	-7	20-25 SSW	blizzard
11	0800	50.0	-10	10-15 SSE	clearing skies, ground haze
	1100	50.0	-7	10-15 SSE	clearing skies, ground haze
	1110	50.0	-5	10-15 SSE	clearing skies
	1145	50.0	-4	12-15 SSE	clearing skies
	1400	50.0	-7	12-15 S	clearing skies
	1530	50.0	-8		clearing skies
	1700	53.0	-9		clearing skies
	1900	58.0	-10		clearing skies
	1920	59.0	-11		clearing skies
	2230	60.0	-12	7-10 S	cloudy
12	0800	60.0	-10	8-10 SE	haze
	1200	60.0	-8	8-10 SE	haze
	1400	60.0	-10	8-10 SE	haze
	1700	66.0	-14	3-5 SE	clearing skies
	1800	69.0	-16		
	2145	70.0	-24		
	2245	70.0	-26	6-8 SE	clear skies
	2400	70.0	-28	6-8 SE	clear, cold
13	0100	70.0	-29	3-5 SE	clear, cold
	0140	70.0	-27	3-5 SE	clear, cold
	0730	70.0	-26	12-14 SE	sunny
	0830	70.0	-25	12-14 SE	sunny
	1100	70.0	-24	15-18 SE	sunny
	1420	70.0	-22	15-18 SE	sunny
	1600	76.0	-22		
	1800	76.0	-26		
	1915	70.0	-25		
	1945	70.0	-28	10-15 SE	overhead clear ;horizon haze
	2315	53.0	-28	15-20 SE	
14	1000	50.0	-18	10-12 SE	sunny, ground haze
	1130	50.0	-16	10-12 SE	sunny, ground haze
	1320	50.0	-11	10-12 SE	sunny, ground haze
	1430	45.0	-12	4 SSE	sunny, no haze
	1700	37.0	-12	3-5 SE	sunny
	1930	37.0	-16	8-10 SE	crisp cool, sunny
	2040	18.0	-15		
	2125	14.0	-15	6-8 SE	
	2200	12.5	-14	8-10 SE	
15	0930	12.5	-10	10-12 SE	sunny
	1130	12.5	-8	6-8 SE	sunny
	1445	12.5	-5		clear
	1545	12.5	-3	6-8 SE	clear
	1730	12.5	-3	3-5 SE	haze
	1755	12.5	-2		haze
	1830	12.5	-2	3-5 SE	haze
	1900	12.5	-3	3-5 SE	light snow flurries
	2300	12.5	-1	very calm	haze
16	0730	12.5	-0.5	5-8 SE	clear
	1000	3.0	0	3-5 SE	clear
	1100	3.0	1	3-5 SE	
	1230	End Moraine	4		clear

GPO 824108-2